LA-UR-14-26830

Los Alamos NATIONAL LABORATORY

EST. 1943

Los Alamos in Space

Intelligence and Space Research Division

Herb Funsten, ISR Division Chief Scientist

Aug. 26, 2014

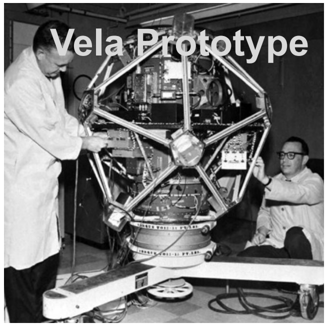
Precipitating Events

- **1952-1964** Advances in Nuclear Weapons
  - *1st US (1952) and Soviet (1953) thermonuclear devices*
  - *Britain, France, and China join the club*
- **1958** Unilateral US & Russia moratoriums
- **1959** US DARPA & AEC starts Project Vela ("watchman") using Los Alamos & Sandia expertise
- **1961** Russia breaks self-declared moratorium: 45 tests (atmospheric and underground) in 100 days
  - *US responds in kind*
- **1963** Limited Test Ban Treaty: US, USSR & UK
  - *Prohibits nuclear detonations in the atmosphere, outer space, or under water*
  - *1st Vela launch: space-based treaty verification*
- Other treaties:
  - *1974: Threshold Test Ban Treaty (ratified)*
  - *1976: Peaceful Nuclear Explosions Treaty (ratified)*
  - *1996: Comprehensive Test Ban Treaty (not US-ratified)*

LANL in space : intimately tied to Nuclear Detonation Detection mission


1961 Tsar Bomba, 50 Mt


Starfish Prime: *400 km 1.4 Mt*


Vela Prototype


LTBT Signing

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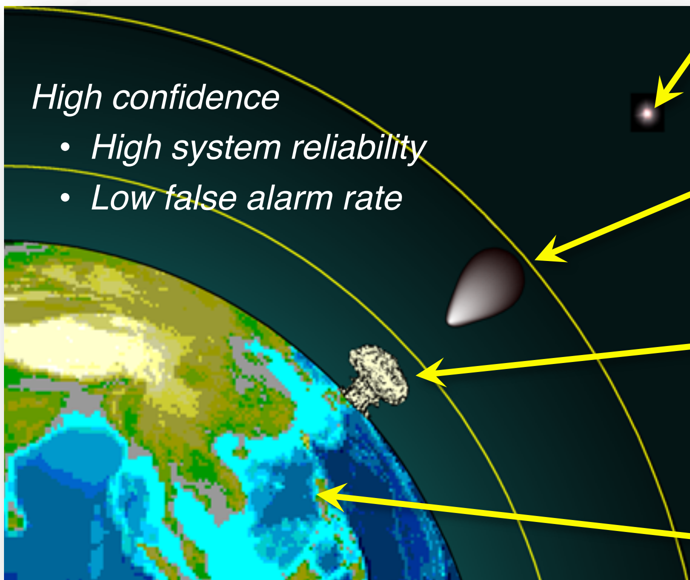
LANL's Nuclear Detonation Detection Mission

Multiple phenomenologies are used to detect, locate, identify and characterize nuclear detonations anywhere, any time



Space NuDet
- *Gamma Rays*
- *Neutrons*
- *X-rays*

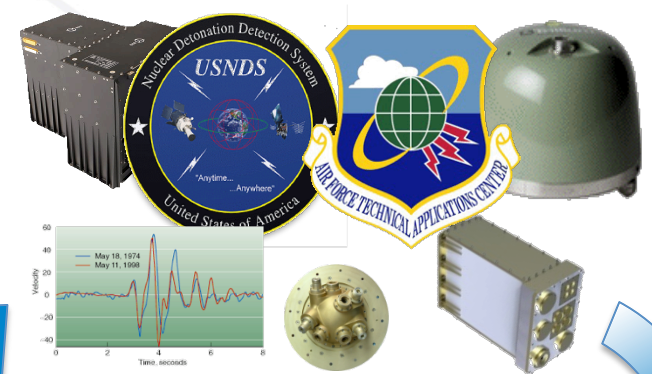
High-altitude NuDet
- *Gamma Rays*
- *Neutrons*
- *Optical*

Low-altitude NuDet
- *Optical*
- *Electromagnetic Pulse*
- *Infrasound*
- *Radionuclides*

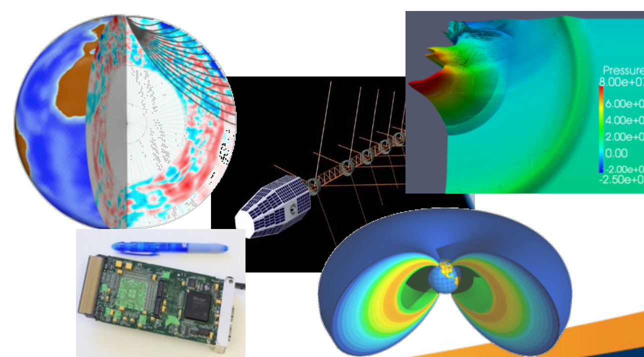
Below-ground NuDet
- *Seismic*
- *Hydroacoustic*

Understanding the natural environment is also a core program element:
- Backgrounds in radiation instrumentation
- Space situational awareness

Operational Sensing Systems



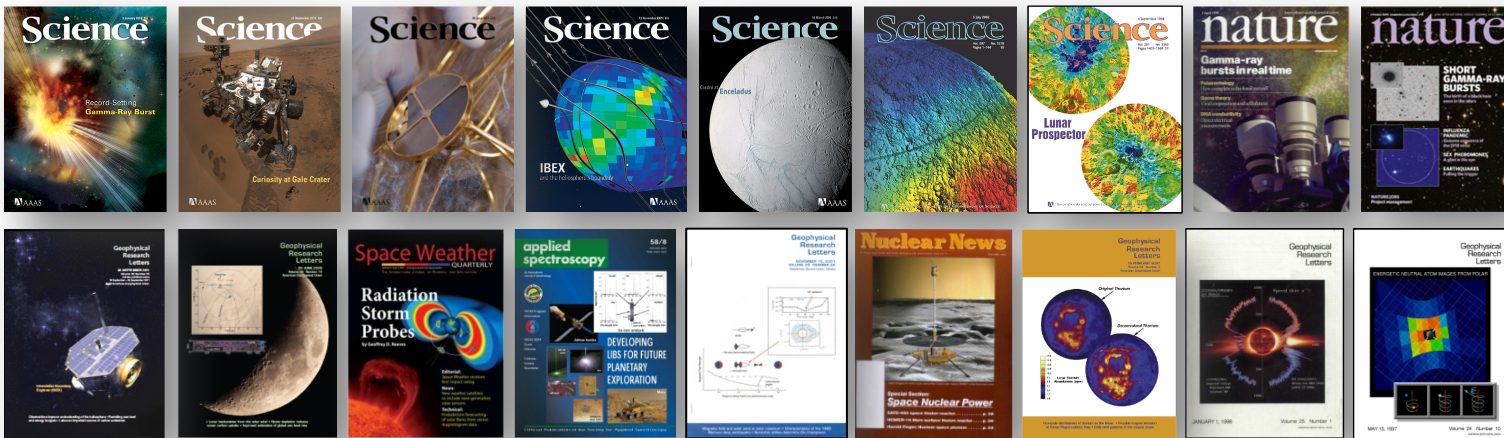
Research & Development



LANL ST&E Research: *Maintaining and Developing World-Class Capabilities that Support the National Security Mission*

Los Alamos in Space: *Supporting the National Security Mission through a Rich Cycle of Innovation and Discovery*

- Signature Discovery



- Revolutionary Measurement: *a quest for the unknown, allow for the unexpected*
- Forward Deployment: *harsh environment, limited resources, autonomous operation*

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LANL's Thinking Telescopes

Discovering New Objects in Space

Telescope Conops: Wide FOV monitoring, rapidly-slewing foveal follow-up

Autonomous and coordinated: ≥6 operational telescope systems

Parallax and coverage: NM sites and HI

Extreme slewing: 50°/sec and 50°/sec^2

Embedded health monitoring, fault detection: vibration monitors

Real-time object ID & classification: 150,000 objects every 20 sec, catalog comparison, queue and prioritize anomalies for real-time follow-up

- *Photometric: brightness vs time*
- *Astrometric: location/spatial track vs time*

	Full Sky Monitor	Fast Follow-up
Telescope Systems	Raptors Q (R2D2), A, B	Raptors A,B,Q/P,T
Pixel Resolution	14-110 asec *(0.004°-0.3°)*	1.5 asec *(0.0004°)*
Sensitivity (R)	~10th to ~16th mag	~17th to ~19th mag
Sky scan & photometric reduction	1.5x10^5 objects every 20 sec	
Slew rate, accel/decel	50 deg/sec, 50 deg/sec^2	

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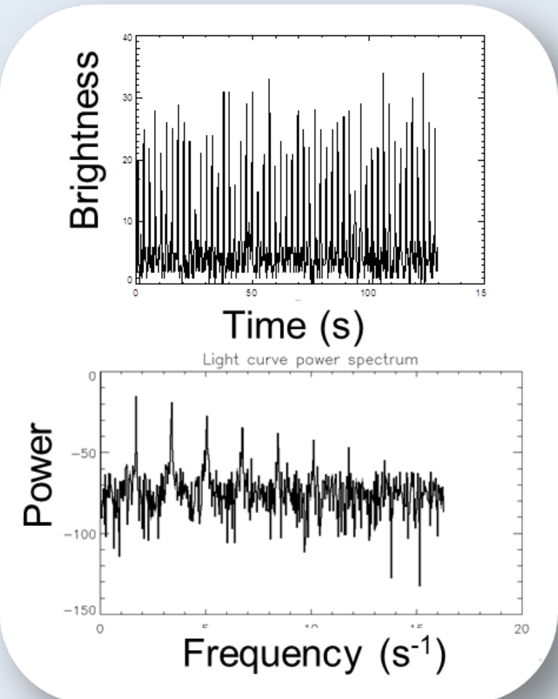
LANL's Thinking Telescopes

Discovering New Objects in Space

Fingerprinting Spacecraft

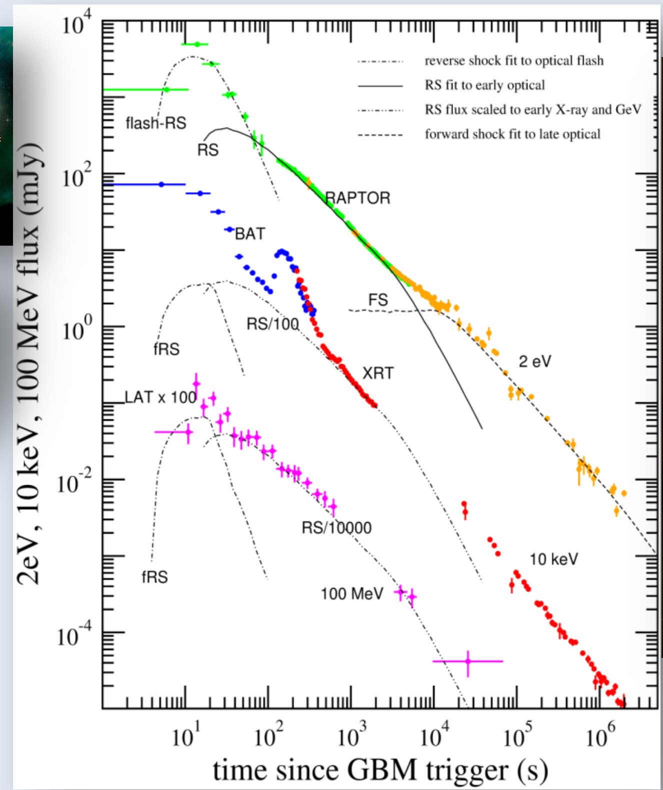


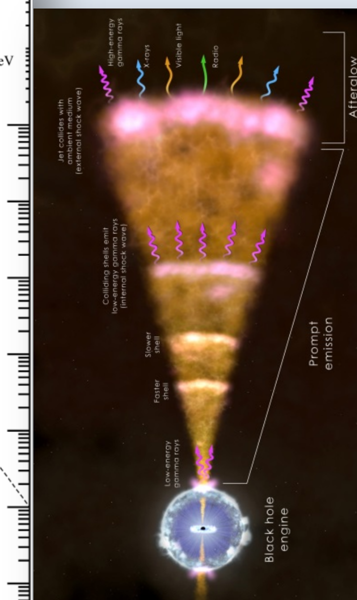
- Light curve of decommissioned MCI commsat (SBS-1)

- Spin period = 0.59335 s

Gamma-Ray Burst 130427A

- Brightest in more than two decades; 3.6 billion light years away
- LANL discovery: exceptionally bright optical flash, establishes the origin of the gamma-ray "afterglow" as a reverse shock





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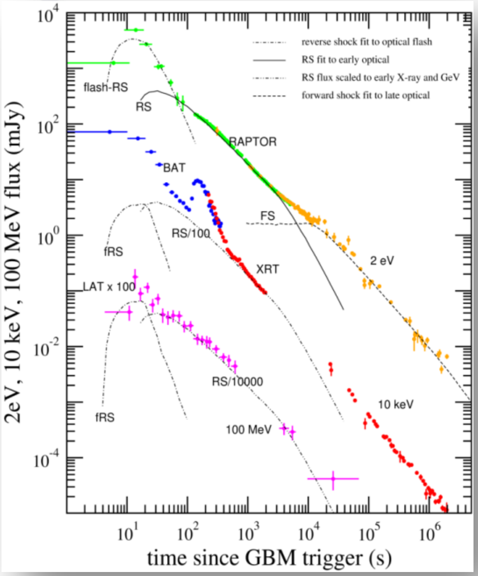
Back to the Future: *Supernovae and Our Evolving Universe*

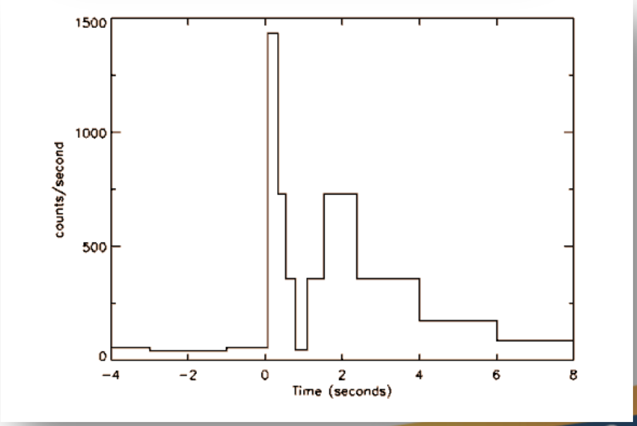
Exploding stars, a window into the early universe and stellar evolution:

- **Discovery by Thinking Telescopes of fundamental supernova shock processes *(Vestrand et al., 2014)***



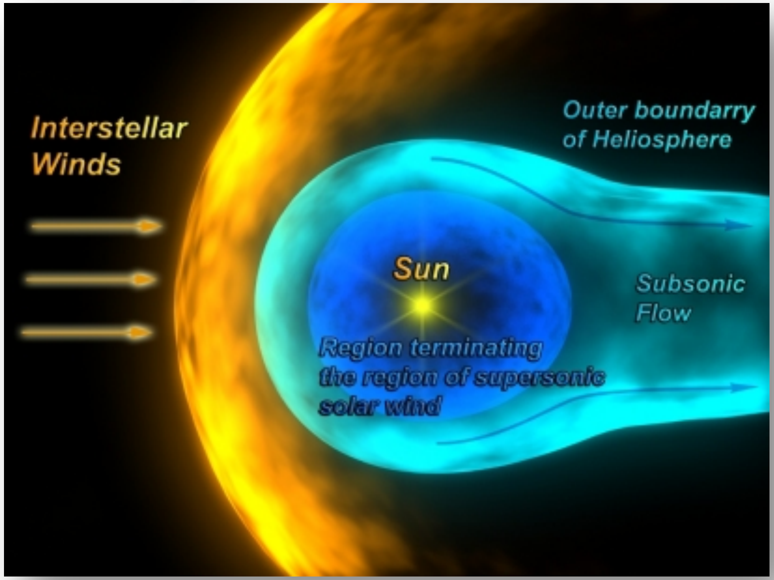
Touched by a supernova:

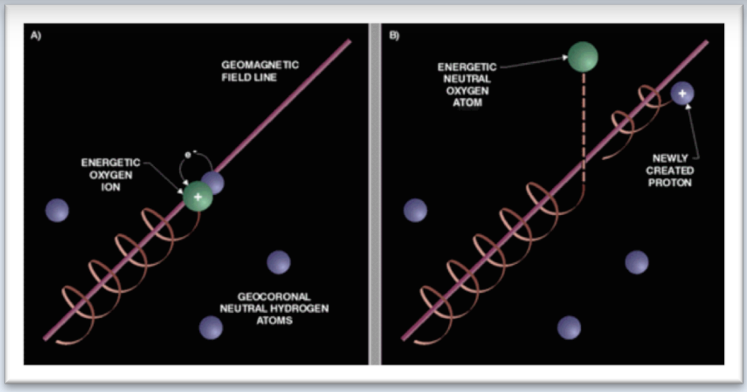
- **Discovery by Vela of gamma ray bursts *(Klebesadel et al., 1973)***



Interstellar Boundary Explorer (IBEX)

Understanding the Sun's Interaction with the Interstellar Medium





Neutral Atom Imaging:

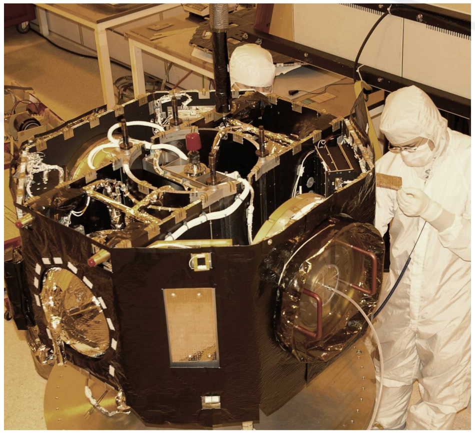
- *Plasma ion* grabs an electron from ambient *cold neutral atom* and becomes an *energetic neutral atom (ENA)*
- ENAs follows ballistic trajectories: long distances in straight lines

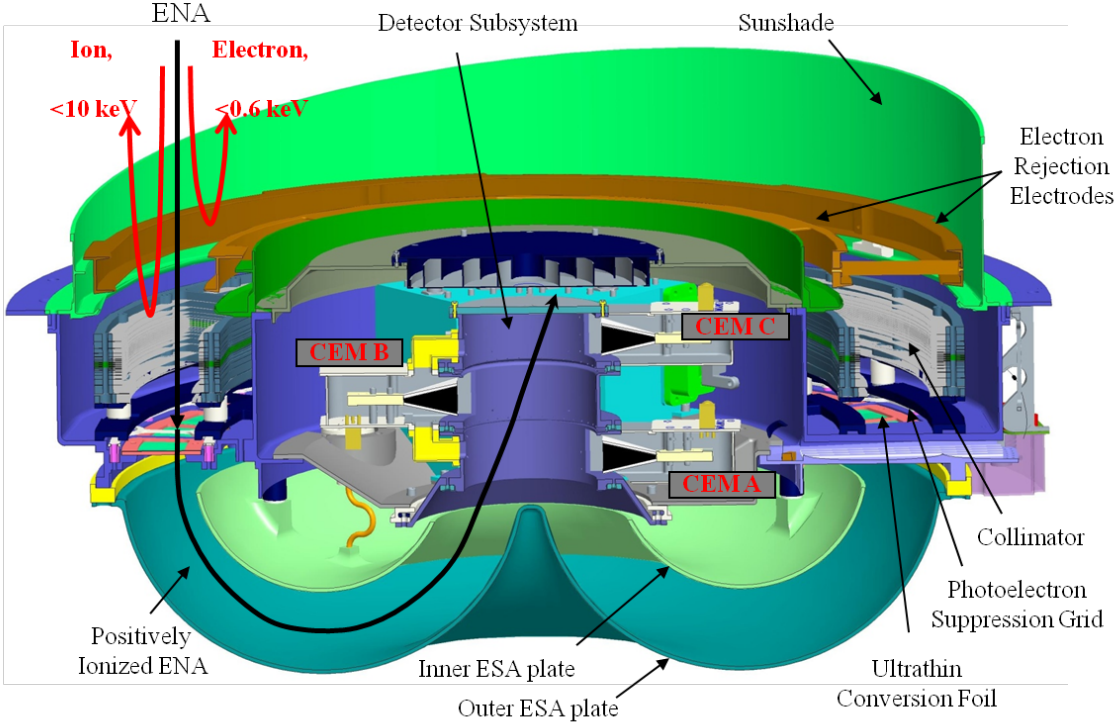
LANL-led IBEX-Hi Imager *Understanding the Sun's Interaction with the Interstellar Medium*

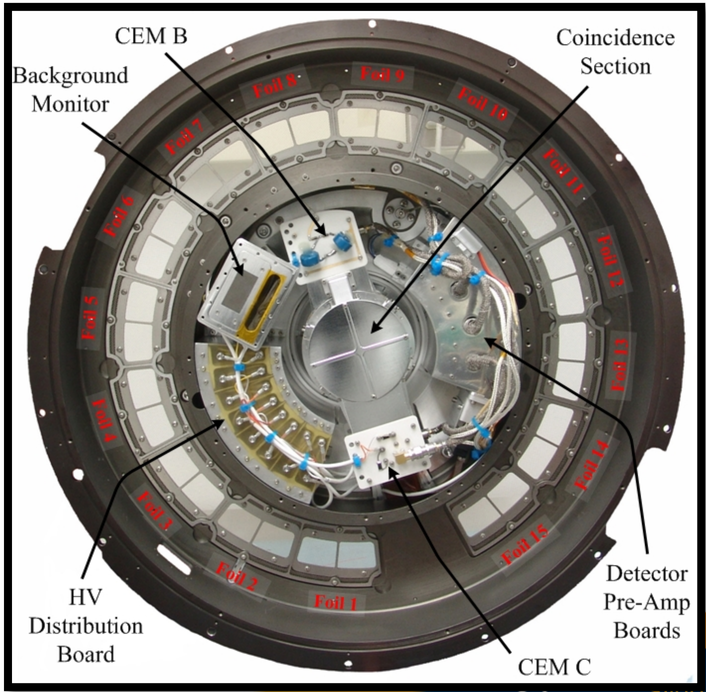
<u>Measurement challenge:</u> ENAs difficult to detect; high background environment

<u>Measurement Strategy:</u>

- First convert ENAs to ions using 150 cm^2 aperture of carbon foils, 50 atomic layers thick







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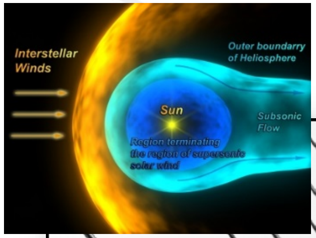
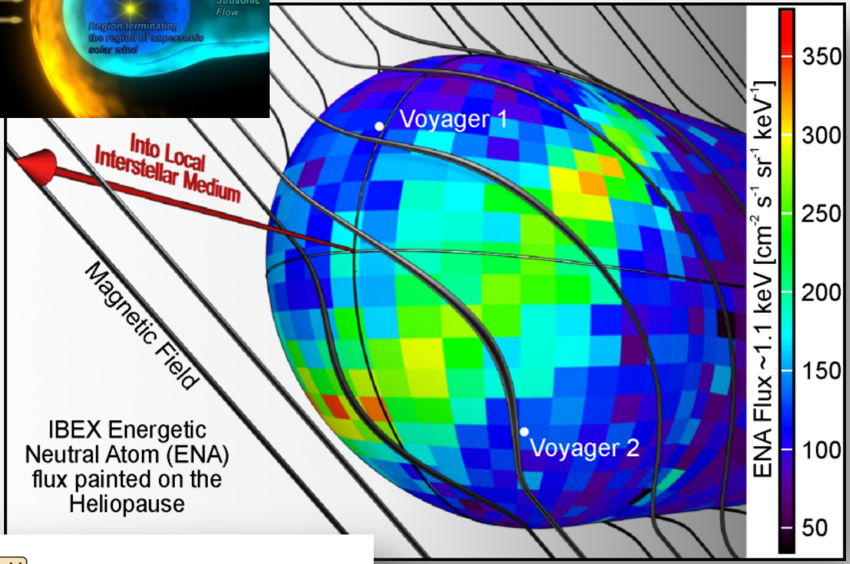
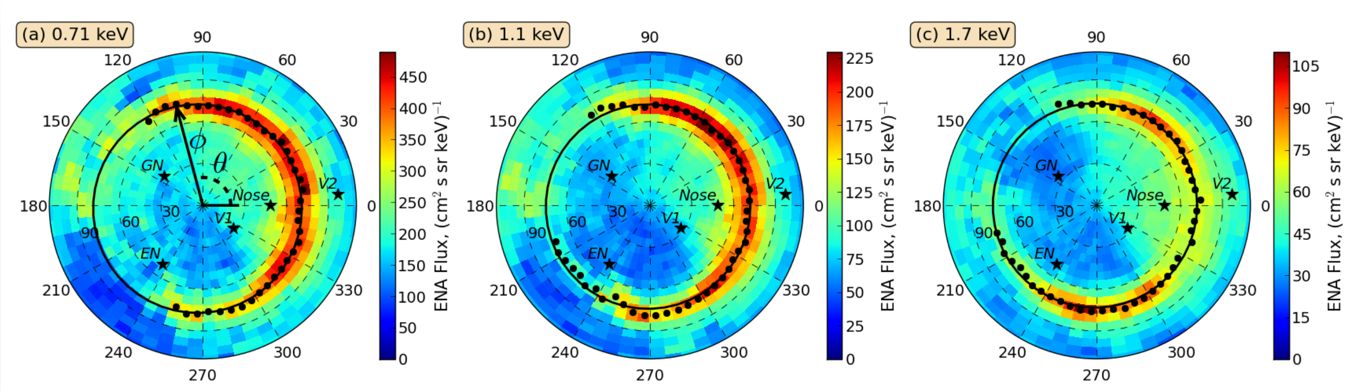
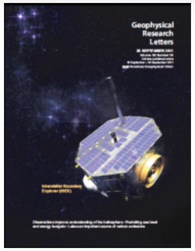


Discovery:

- An extremely circular "ribbon" of ENA emission
- At least 14 theories published to explain it; no consensus
- Center of ribbon is believed to be the direction of the interstellar magnetic field

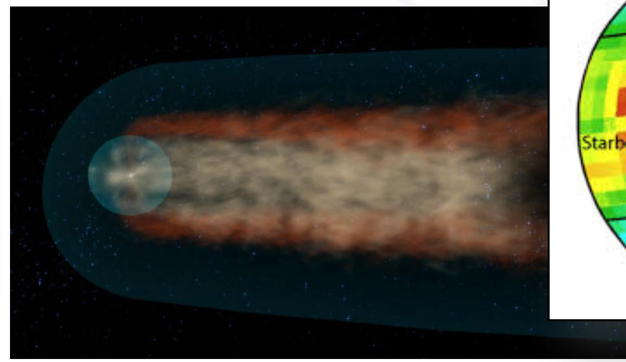


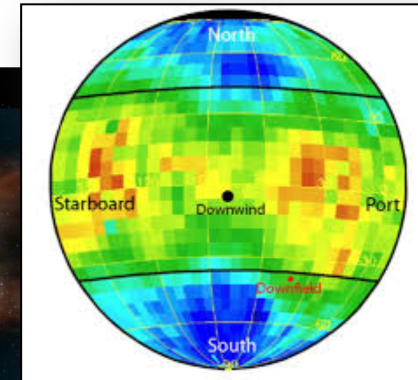




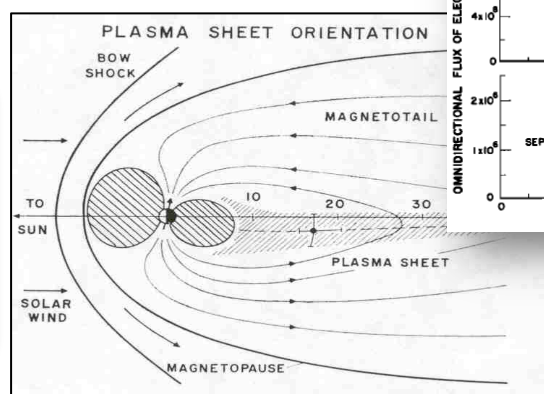
Back to the Future: *Wakes of the Earth and Sun*

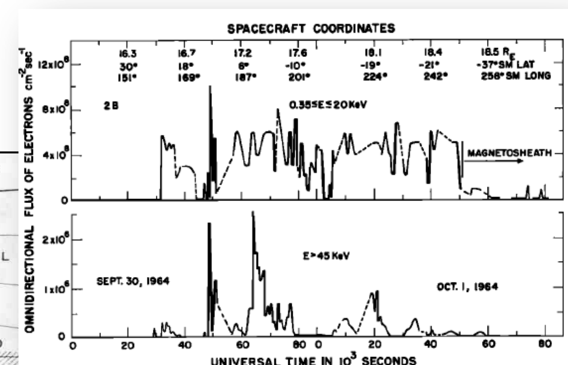
The Sun is an obstacle in the interstellar medium:
- **Discovery by IBEX of the heliotail** *(McComas et al., 2013)*



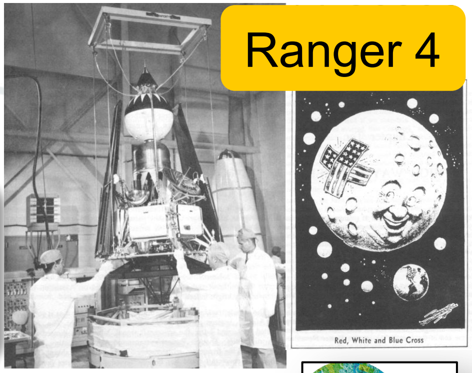


The Earth is an obstacle in the solar wind:
- **Discovery by Vela of the Earth's plasma sheet** *(Bame et al., 1966, 1967)*



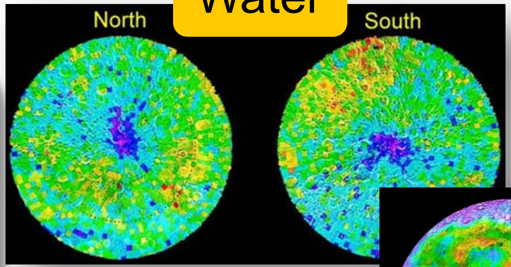


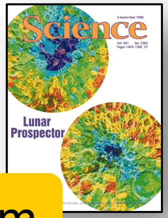
Back to the Future: *The Moon*

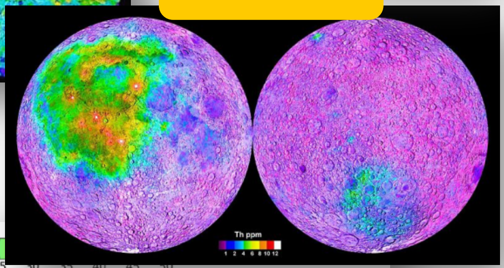


Is it cheese?

- **1st attempts of in-situ lunar composition on NASA's Rangers 3-5 (*Van Dilla et al., 1962); Atlas-Agena launch vehicles***

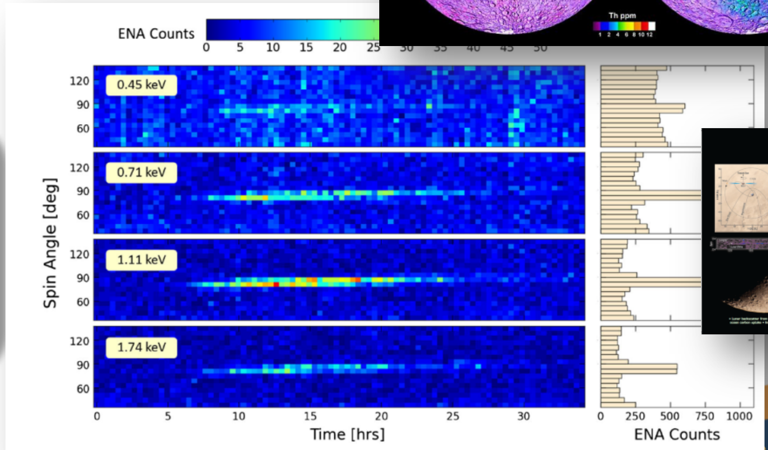


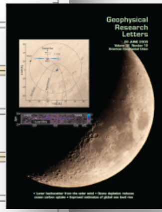




It's quite complex:

- **Discovery by Lunar Prospector of water at the poles (*Feldman et a., 1998*)**
- **Discovery by Lunar Prospector of the global elemental distribution *(Lawrence et al., 1998)***

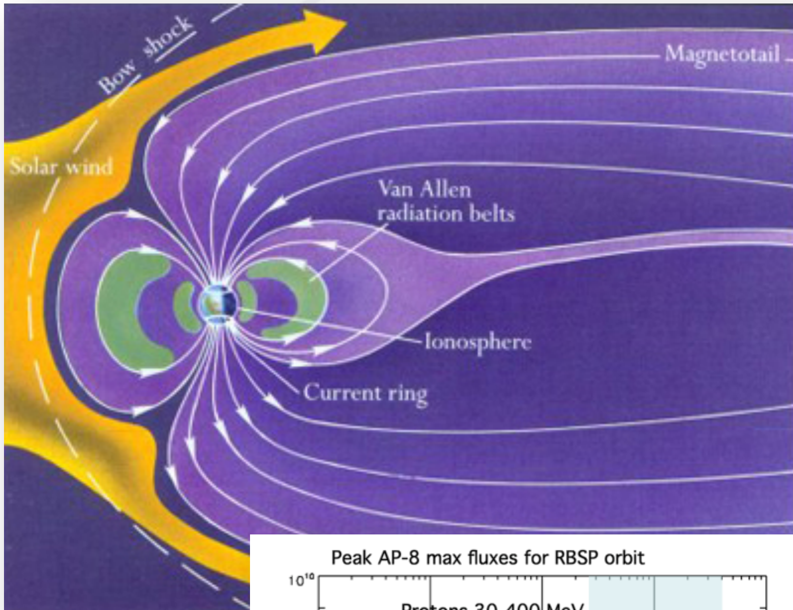


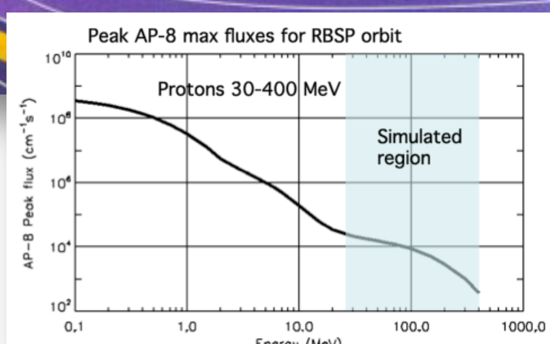


Dynamic processes at the surface:

- **Discovery by IBEX of the reflection of the solar wind from the Moon *(McComas et al., 2009, Funsten et al., 2013)***

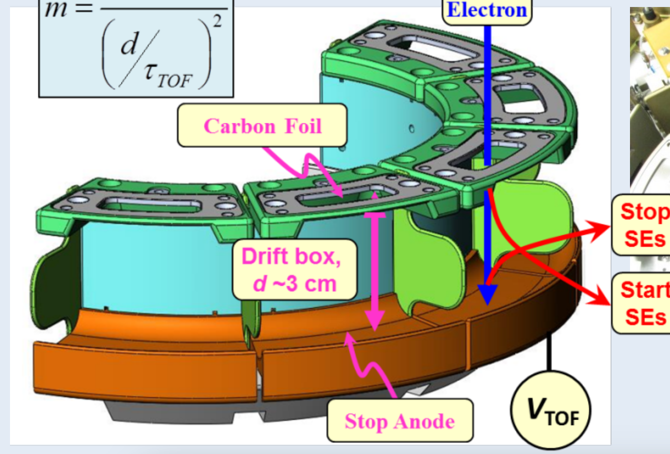
NASA's Van Allen Probes *Understanding the structure and dynamics of the Earth's radiation belts*

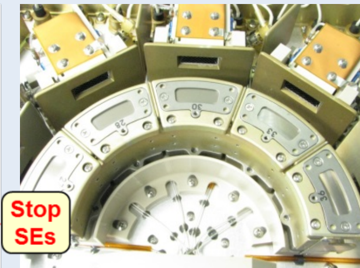


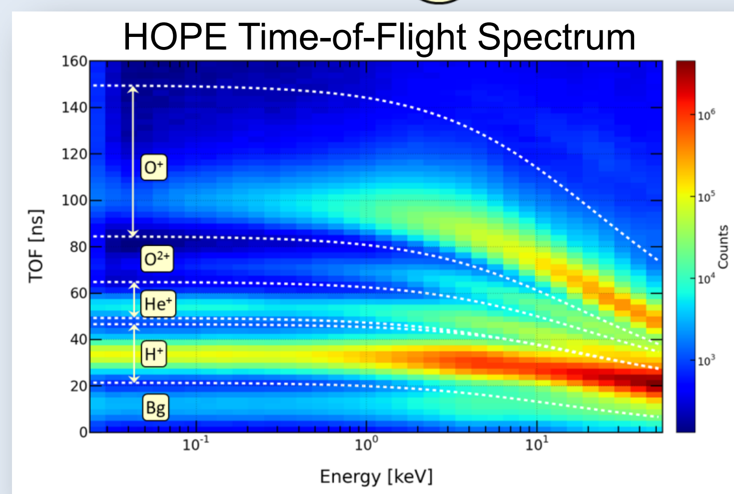


LANL-led Helium, Oxygen, Proton, and Electron (HOPE) Mass Spectrometer

$$m = \frac{2E}{\left(d/\tau_{TOF}\right)^2}$$







Back to the Future: *The Harsh Space Environment of Earth*

Drivers of the Van Allen Radiation Belts:

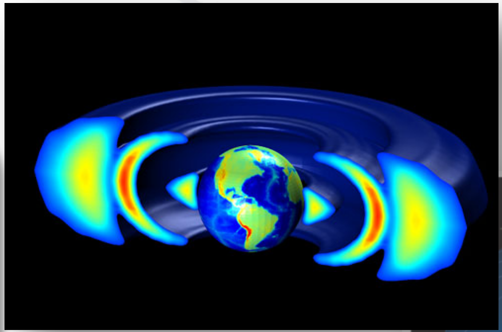
- **Discovery of a third radiation belt by Van Allen Probes *(Baker et al., 2013)***
- **Discovery of the electron acceleration process by Van Allen Probes *(Reeves et al., 2013)***

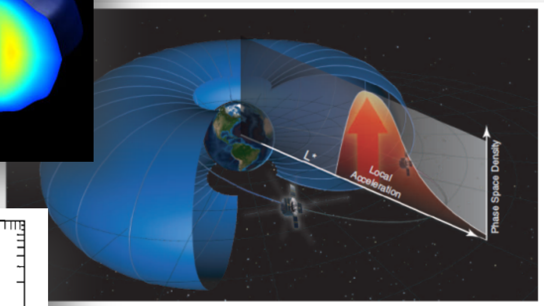
Space is harsh:

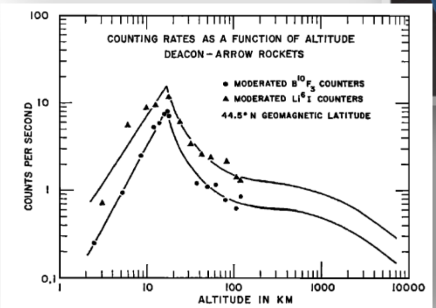
- **Discovery of neutrons on Deacon Arrow VP-8 & VP-12; Atlas Pod 7-III *(Bame et al., 1960, 1963)***

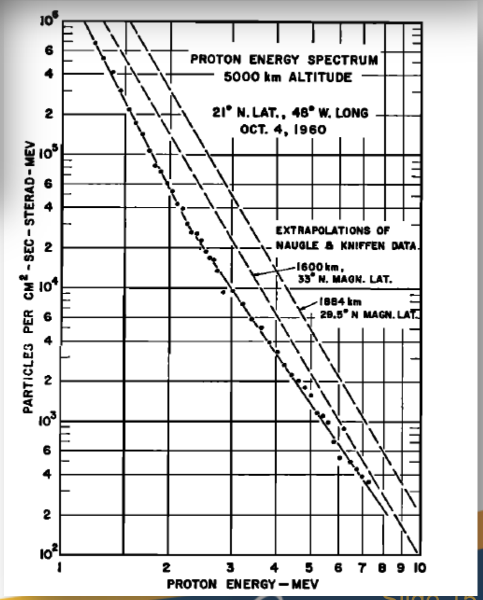
Main ingredient of the Van Allen Radiation Belts:

- **Discovery of protons in the radiation belts by NASA Scout ST-2 *(Bame et al., 1962, 1963);***
- ***Scout: 4-stage, all solid fuel***









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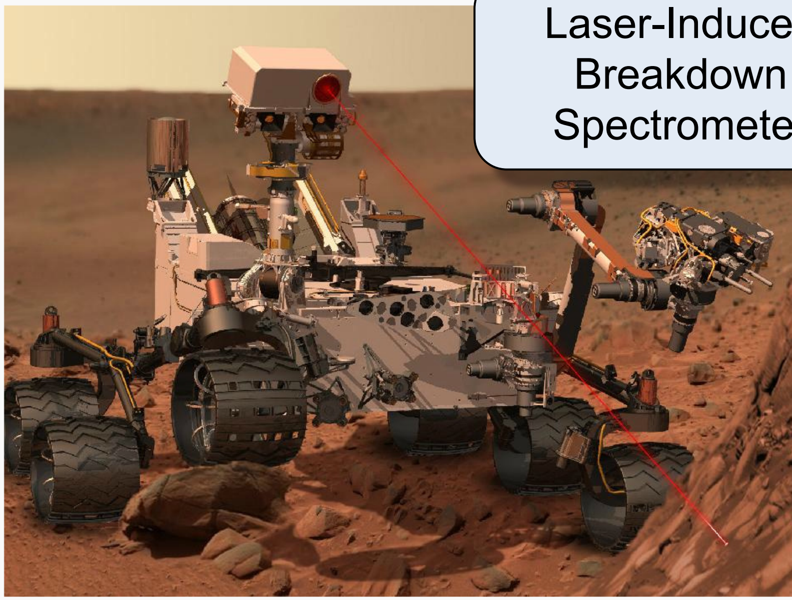
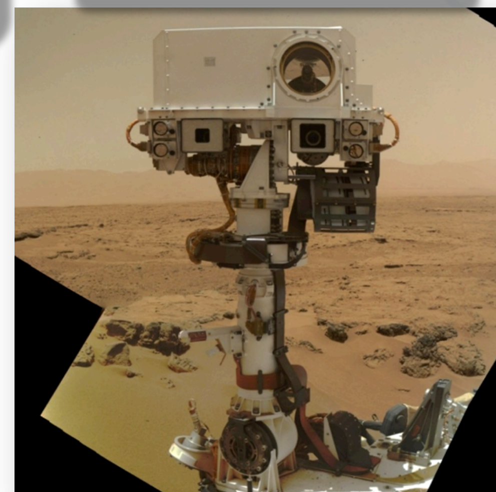
ChemCam: *Understanding the biological potential, role of water, and geological and geochemical evolution of Mars*



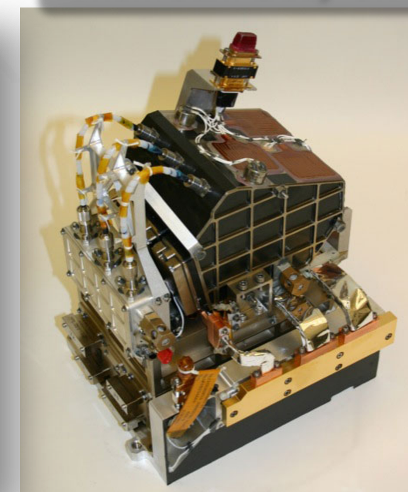
Laser-Induced Breakdown Spectrometer

Yellowknife Bay rock: 3.8-4.4 by old, 20% clay, neutral pH, exposed to water < 100 mya

ChemCam Mast Unit



ChemCam Body Unit



3 ChemCam spectrometers:
- Light from Mast unit split by demultiplexer
- 240-336 nm, 380-470 nm, 470-850 nml

Mars Science Laboratory: *Understanding the biological potential, role of water, and geological and geochemical evolution of Mars*

Yellowknife Bay, Mars
Not as wet and wild as predicted!

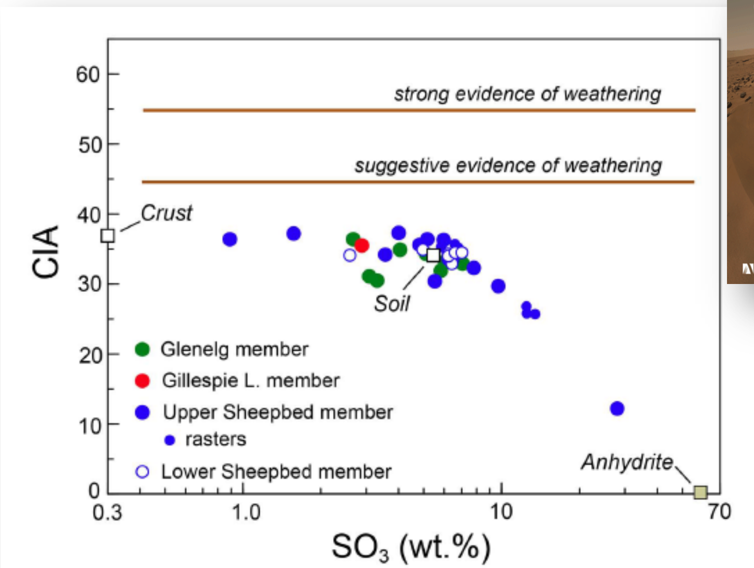
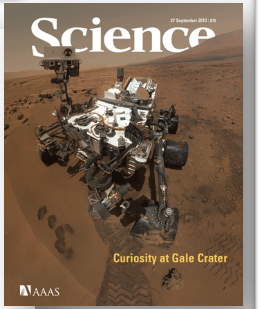
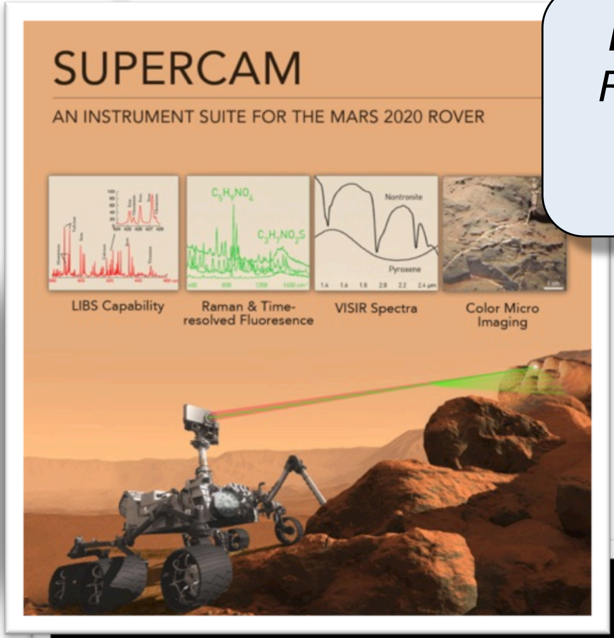


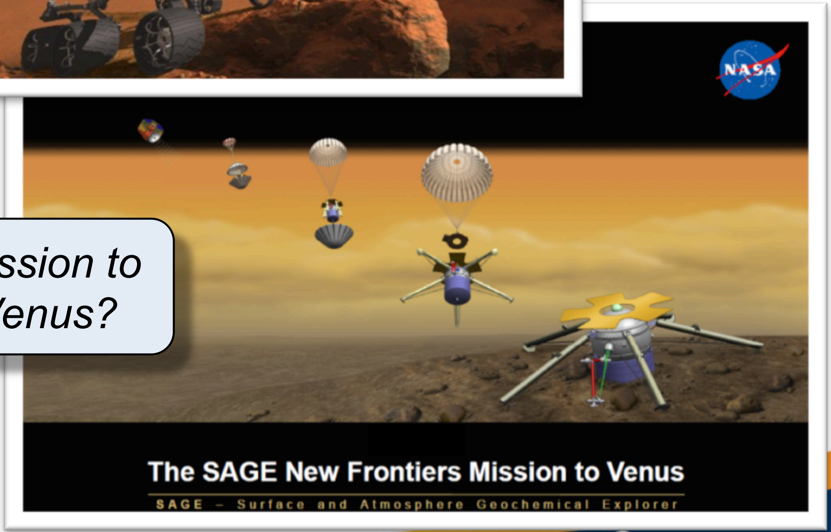
Fig. 3. Plot of CIA versus SO_3 contents for Yellowknife Bay formation APXS analyses. Shown for reference, as open squares, are average martian crust (12), local soil (64), the composition of anhydrite ($CaSO_4$) and horizontal lines that show the CIA values expected for basaltic sedimentary rocks that have experienced a chemical weathering history.



CIA = Chemical index of alteration (Ca, K, Na)



LIBS + Raman: Mars 2020



Mission to Venus?